FRASER RIVER
Estuary Management Program

Waste Management Activity Program
Discussion Paper

Potential Groundwater Contamination In The Fraser River Estuary

December 1990

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Potential Groundwater Contamination In the Fraser River Estuary

Prepared by

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For the

Waste Management Activity Program

Working Group

December 1990

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Preface

The Waste Management Activity Program is one of seven activity programs under the Fraser River Estuary Management Program, each responsible for preparing activity plans addressing estuary wide activities. A Recommended Waste Management Activity Plan (Waste Management Activity Program Work Group, 1990), was produced earlier. Discussion papers covering in more detail some areas of concern for waste management in the Fraser River estuary have since been prepared. They include:

- Agricultural Runoff Contamination in the Fraser River Estuary
- Potential Groundwater Contamination in the Fraser River Estuary
- Potential Water Contamination From Miscellaneous Sources, Fraser River Estuary

Each discussion paper contains technical information, management strategies, and action elements required for the management of various waste sources to the estuary. Not all available information may be included, nor may all possible management alternatives be discussed. Further work may be required. The purpose of the discussion papers is to stimulate discussion regarding policy actions for control and management of wastes in the Fraser River estuary.

Copies of these reports are available from the Fraser River Estuary Management Program office.

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Introduction

Groundwater may refer to any water in the ground, or it may be restricted to refer to water below the level at which pore spaces in the soil are saturated. The top of this saturated zone is the water table, above the water table is the unsaturated zone. Water movement in these zones may be slow or rapid, depending on the coarseness and composition of soil material. Groundwater flow is driven by gravity and hydraulic pressure differences. While most flow is downward or lateral, some may be upwards. In humid regions such as the Fraser River estuary area, the water table is near the surface, and groundwater maintains flows in streams and rivers.

Groundwater withdrawals through wells may be made for domestic, industrial, or agricultural purposes. This groundwater supply may or may not be balanced by groundwater recharge, the proportion of precipitation that infiltrates the soil plus other additions. Most groundwater systems in the Fraser Lowland are local or intermediate flowing systems, with residence times between recharge and discharge ranging from less than 25 years up to 100 years.

Contaminants introduced to the ground may potentially pollute groundwater. Concerns are for possible environmental impacts and health risks imposed by contaminated groundwater withdrawn through wells, and for contamination of surface waters by discharge of groundwater. Due to size, pattern of water movement, and inaccessibility, once groundwaters are contaminated remediation may be futile or expensive.

In this background paper, a general discussion of the supply, recharge, and contamination of groundwater in the Fraser River estuary area is followed by sections on various potential groundwater contamination sources. These include solid waste dumps and landfills; liquid discharges to ground; spreading of fertilizers, soil conditioners, sewage sludge, and pesticides; and leaking underground storage tanks. The nature and magnitude of the waste management problem is defined for each source, along with the legislation, programs, and current and recommended best management practices. Action needs, which may include research, public awareness, or development and implementation of control measures, are then summarized.

Groundwater Supply

In the Fraser Lowland, which includes the east and south Surrey, Langley, and Maple Ridge part of the estuary watershed area and extends up to Hope, groundwater supplies accounted for 44% of total water requirements in 1981 (Halstead, 1986). Langley City and Municipality were supplied 60% from wells in 1981, the rest from the Greater Vancouver Water District. The GVWD supply is currently being extended through Langley. About 15% of Surrey water consumption in 1981 was from wells, the rest was from the GVWD. All of White Rock 1981 consumption was from a single production well. Total 1981 Fraser Lowland groundwater withdrawals for all uses were just under 30 million m^3, 71% from production wells and the remainder from domestic wells (Halstead, 1986). While records of groundwater withdrawals and locations of wells are maintained by municipalities and the Water Management Branch, Ministry of Environment, summary information is generally not easily available.

Groundwater maintains flows in local streams and tributaries. Most of the 180 stormwater outfalls inventoried in 1980 (Krahn et al., 1981) were found to flow during dry periods, with a total dry weather volume of 356,000 m^3/day during summer months (Clark et al., 1981). The annual stormwater discharge is estimated at 287 million m^3/year, or a 786,000 m^3 daily average. This dry weather flow is groundwater infiltation of stormwater sewers or other ground storage, and illustrates groundwater influence on surface water flows.

Groundwater Recharge

The amount of annual groundwater recharge in the area surrounding the Fraser estuary is estimated by determining annual precipitation, adding amounts from irrigation, lawn watering, and other additions, and subtracting surface runoff and evapotranspiration.

The watershed area of the Fraser below Kanaka Creek, including Boundary Bay and its tributaries, is about 1,700 km^2. Annual precipitation over the area varies from 850 mm at Tsawwassen to 1,900 mm on Burnaby Mountain and at higher elevations along tributaries north of the Fraser (AES, 1982; Wright and Trenholm, 1969). If average precipitation is estimated as 1,400 mm per year, then about 2,380 million m^3 of water precipitates into this part of the watershed annually.

Surface water withdrawal licences in the area total over 65 million m^3 per year (Water Management Branch files), though actual withdrawals are likely to be lower than this. Except for irrigation, most withdrawn water is likely to be discharged to sewer or to ditches and streams. Water withdrawal licenses for irrigation totalled 5.3 million m^3/year. Piped-in

water from the GVWD Capilano, Seymour, and Coquitlam reservoirs totalled 370 million cubic meters in 1989. Only a small part of this, representing lawn and garden use, car washing, and leakage, would replenish groundwater.

The proportion of precipitation and other additions that infiltrates to groundwater depends on climate, topography and surface composition, vegetation cover and composition, and soil and near surface geological materials. Climate affects the amount of precipitation and evapotranspiration. The intensity of rainfall affects the amount of infiltration. A flat surface allows water to stand until it soaks in, on a slope it is more likely to run off. Relatively impenetrable surfaces such as hard packed soil, cement, and asphalt, yield more runoff. Vegetation cover inhibits runoff, and increases evapotranspiration. Soils and near surface geological materials affect rates of water entry and groundwater movement.

Based on these environmental variables, coefficients are derived expressing the expected proportion of precipitation that becomes runoff, evaporates, or infiltrates to recharge groundwater. In humid areas, such as the Fraser estuary, groundwater recharge may amount to 40 - 50% of precipitation and additions (CAST 1985). Assuming a groundwater recharge coefficient of 0.45, a rough estimate of groundwater recharge in the area draining to the Fraser estuary and Boundary Bay would be 1,000 million m^3 annually.

Groundwater Contamination

Much of this discussion on groundwater contamination and transport processes is drawn from CAST (1985) and Halstead (1986).

Contamination of groundwater is a concern where wells are used for drinking water, industrial purposes, or irrigation. Contaminants injected into groundwater may eventually be transported to surface waters where they cause environmental problems. The extent of the problem may be difficult to determine as groundwater systems are complex, relatively slow moving, and not easily apparent from the surface. By the time contamination is discovered, it may have spread enough that remediation is futile or expensive. Some contaminants are not transported by groundwater, or are neutralized during transport.

Contaminants in soil may be present in the air or water occupying the pore spaces, on the surface of the soil solids, or as discrete undissolved particles. Under normal circumstances, chemicals are transported to groundwater in solution and not as gases or components of solid particles. Dissolved chemicals are moved by two mechanisms that occur simultaneously: mass flow, the movement of water in which the chemicals are dissolved; and

diffusion, the random motion of constituent molecules and ions. Water movement and dispersal is more effective in transport over longer distances. Transport may be inhibited by the tendency of chemicals to adsorb, or attach to surfaces. The amount of clay minerals and organic material in the soil affects the rate of adsorption, decreasing the rate of transport of chemicals because the amount in solution is decreased. Dissolved materials may degrade, and degradation takes place at different rates. Chemicals that decompose by 50% within a few weeks or less usually disappear before traveling the few meters needed to reach the water table.

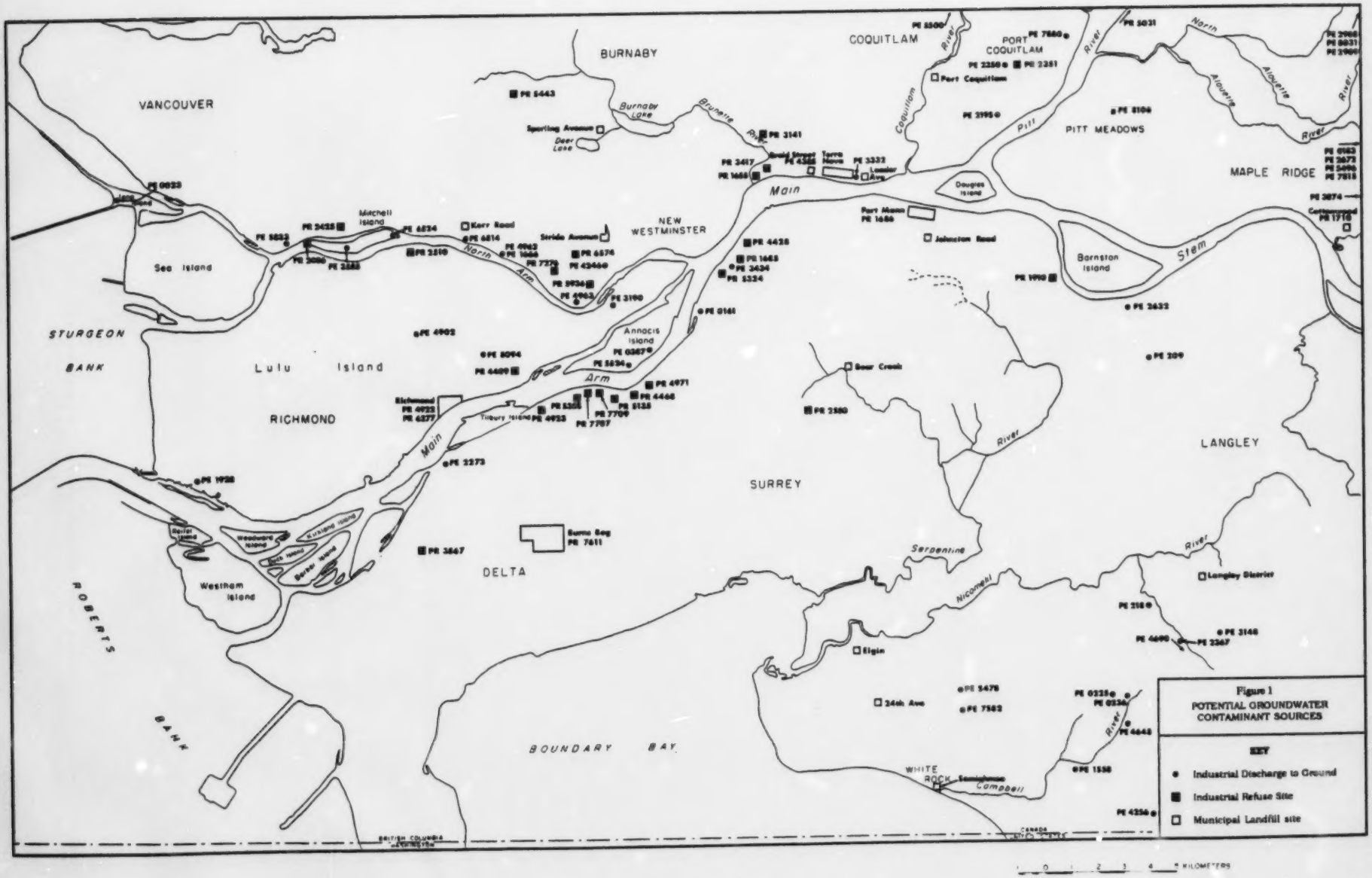
Between point of recharge and point of discharge, the quality of groundwater changes by increasing in total dissolved and suspended particles and the relative proportions of constituents. Constituents are derived from both natural sources and man-made waste sources. In the Fraser Lowland, groundwater evolves from precipitation, which is weakly acidic, to water with total dissolved solids in the order of 500 mg/L. Fraser Lowland groundwater is classified as soft to moderately hard and, aside from contaminants from man-made sources, water quality problems are usually limited to iron and manganese concentrations. However, much of the Fraser Lowland is vulnerable to pollution from agricultural, commercial, and domestic uses of fertilizer, pesticide, irrigation, and wood waste. In developed areas, leaking storage tanks, leachates from landfills and storage piles, and spills contribute contaminants. Contaminants of particular concern include nitrites, phosphate, metals, and hydrocarbons.

Municipal Landfills

Nature and Magnitude of the Problem

Municipal waste generated in the Greater Vancouver Regional District totalled 1.2 million tonnes in 1989. About 45% of this was from households, the remainder from commercial and industrial sources. Traditionally, this waste has been disposed of in municipal landfills.

A number of municipal landfills have collected refuse from local areas since the Fraser River estuary area was originally settled in the 1800s (tables 1 and 2). Early landfills tended to be small, collecting refuse from local areas and dumping it in convenient places. Some such sites may have been forgotten. Over the years, an evolution in landfill management practices has occurred so that more recent landfills serve a wider area and use environmental practices such as intermediate and final cover. While the trend now is towards recycling, reusing, and


VANCOUVER
BURNABY
COQUITLAM
PORT COQUITLAM
PITT MEADOWS
MAPLE RIDGE
NEW WESTMINSTER
Sea Island
Lulu Island
RICHMOND
Annacis Island
Barnston Island
SURREY
LANGLEY
DELTA
Westham Island
Douglas Island
Tilbury Island
Burnaby Lake
Deer Lake
Mitchell Island
Kerr Road
Stride Avenue
Port Mann
Johnston Road
Bear Creek
Elgin
24th Ave
Langley District
WHITE ROCK
Semiahmoo
Campbell
Fraser River
North Arm
Main Arm
Pitt River
Coquitlam River
Alouette River
Serpentine River
Nicomekl River
STURGEON BANK
ROBERTS BANK
BOUNDARY BAY
Burrard Inlet
Woodward Island
Kirkland Island
Beaver Island
Sunny Bog
PE 7611
PE 3667
PE 2273
PE 1928
PE 4902
PE 5094
PE 4469
PE 4922
PE 4277
PE 5305
PE 7709
PE 7707
PE 4971
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PE 2251
PE 2195
PE 5031
PE 8104
PE 3874
PE 1716
PE 2366
PE 3673
PE 5496
PE 7815
PE 2366
PE 8031
PE 2900
PE 216
PE 4690
PE 3146
PE 2367
PE 5478
PE 7582
PE 0225
PE 0236
PE 4648
PE 1558
PE 4256
Figure 1
POTENTIAL GROUNDWATER CONTAMINANT SOURCES
KEY
Industrial Discharge to Ground
Industrial Refuse Site
Municipal Landfill site
0 1 2 3 4 5 KILOMETERS

resource recovery of solid waste, and mass reduction methods such as incineration, landfilling remains the principle means of refuse disposal in the region.

Table 1 SMALL MUNICIPAL LANDFILLS

Name	Affected Water Body	Status	Leachate Impacts
Johnston Road, Surrey	Main Stem	Closed 1969	Yes
Port Coquitlam	Coquitlam River, Main Stem	Closed 1979	Unknown
Sperling Avenue, Burnaby	Brunette River, Main Stem	Closed 1967	Unknown
Bear Creek, Surrey	Serpentine River, Bndy Bay	Closed 1967	Yes
Elgin, Surrey	Nicomekl River, Bndy Bay	Closed 1966	Unknown
24th Avenue Surrey	Nicomekl River, Bndy Bay	Closed pre1955	Unknown
City of Langley	Nicomekl River, Bndy Bay	Closed 1978	Yes
Semiahmoo Bay, Surrey	Campbell River, Bndy Bay	Closed pre1965	Unknown

Table 2 LARGE MUNICIPAL LANDFILLS

Permit No.	Name	Affected Water Body	Status	Comments
PR4385	Braid Street	Main Stem	Closed	Leachate collected, discharged to sewer
PR1611	Burns Bog	Main Arm	Open	Leachate collected, discharged to sewer
PR1710	Cottonwood	Main Stem	Closed 1989	Leachate collected, discharged to sewer
*	Kerr Road	North Arm	Closed 1966	Leachate collected, discharged to sewer
PR1351	Leeder Avenue	Main Stem	Closed	Monitored
PR1686	Port Mann	Main Stem	Open	Leachate collected, discharged to sewer
PR6277	Richmond (FRHC)	Main Arm	Closed	Leachate collected, treated on site
*	Stride Avenue	North Arm	Closed 1969	Monitored
PR1639	Terra Nova	Main Stem	Closed 1975	Monitored

* Closed prior to permit provisions of Waste Management Act

All municipal landfills except Burns Bog and Port Mann are now closed. Port Mann, due to be closed about 1995, receives refuse from Surrey and waste transferred from the North Shore Transfer Station and the Coquitlam Resource Recovery Plant. Burns Bog accepts refuse from Vancouver, Richmond, Delta, White Rock, part of Surrey, and the Vancouver Transfer Station. Waste generated in Burnaby, New Westminster, Coquitlam, Port Coquitlam, Pitt Meadows, Maple Ridge, Langley City, and Langley Township is processed through the Burnaby Incinerator, the Coquitlam Resource Recovery Plant, the Langley Transfer Station, or the Matsqui Transfer Station. Wastes from the Matsqui Transfer Station and the Coquitlam Resource Recovery Plant are transferred to the Cache Creek Landfill.

The main concern with municipal landfills is leachate impact on ground and surface waters. Leachate is produced when water infiltrates through the dump and dissolves contaminants. The composition of wastes making up a typical municipal landfill is complex and difficult to characterize. It is not surprising that the leachates generated are also complex and contain a wide variety of contaminants. Generally, leachate from solid waste disposal sites is a mineralized reddish-brown to black liquid containing chloride, iron, copper, sodium, nitrogen, and various organic chemicals. Industrial wastes can add hazardous constituents such as cyanide, cadmium, chromium, chlorinated hydrocarbons, and PCBs (table 3). Net water infiltration and leachate generation occurs at all Fraser River estuary landfills.

A soil cap and provision of adequate surface slopes is usually required to help control infiltrating water. In areas of significant rainfall, however, infiltration and leachate generation cannot be prevented by a soil cover. A rule of thumb for infiltration assumes that 50% of annual precipitation in excess of 500 mm will emerge as leachate, and doubling this will allow a safety margin (Atwater, 1980). In this case, the amount of leachate generated in the Fraser River estuary area could be between 1,850,000 and 3,700,000 m^3/year (table 4). Local circumstances should be considered rather than a rule of thumb; the 24th Avenue fill is covered by a paved road, for example, infiltration will be minimal there. Leachate can also be generated by groundwater flows through the fill mass.

Table 3
GENERAL MUNICIPAL REFUSE LEACHATE COMPOSITION

Parameter	Value Range (mg/L)
Color	0 - 120,000
pH	3.7 - 8.5
Total Carbon	715 - 22,350
BOD	9 - 55,000
COD	0 - 90,000
Acidity (as $CaCO_3$)	0 - 9,590
Alkalinity (as $CaCO_3$)	0 - 20,900
Hardness (as $CaCO_3$)	0 - 22,800
Total Solids	1000 - 45,000
Total Dry Solids	0 - 42,300
Tannin-like compounds	62 - 1,278
Chloride	34 - 2,800
Cyanide	0 - 0.11
Fluoride	0 - 2.13
Nitrogen (as NH_3)	0 - 1,106
Phosphorus (as P_2O_5)	0 - 154
Sulphate	1 - 1,826
Sulfide	0 - 0.13
Calcium	5 - 4,000
Magnesium	16.5 - 15,600
Potassium	2.8 - 3,770
Sodium	0 - 7,700
Arsenic	0 - 11.6
Aluminum	0 - 122
Barium	0 - 5.4
Beryllium	0 - 0.3
Boron	0.3 - 73
Cadmium	0 - 0.19
Chromium	0 - 33.4
Copper	0 - 10
Iron	0.2 - 5,500
Lead	0 - 5.0
Manganese	0.06 - 1,400
Mercury	0 - 0.064
Molybdenum	0 - 0.52
Nickel	0.01 - 0.8
Titanium	0 - 5.0
Vanadium	0 - 1.4
Zinc	0 - 1,000
Toxicity (96 hr LC_{50}) %	38 - 0.062

Metals are total
Based on landfills and test lysimeters
(Source: Cameron, 1978, quoted in Atwater, 1980)

Table 4 POSSIBLE ANNUAL LEACHATE GENERATION FROM MUNICIPAL LANDFILLS, FRASER RIVER ESTUARY AREA

Landfill	Area (ha)	Average Annual Precipitation (mm)	Leachate Generation Minimum (m^3)	Maximum (m^3)
24th Avenue	0.07	1060	230	460
Bear Creek	0.9	1525	4,615	9,230
Braid Street	31	1650	178,250	356,500
Burns Bog	75	1010	191,250	382,500
City of Langley	5.5	1500	27,500	55,000
Cottonwood	10	1650	57,500	115,000
Elgin	2.5	1140	8,000	16,000
Johnston Road	0.2	1575	1,075	2,150
Kerr Road	27	1040	72,900	145,800
Leeder Avenue	27	1650	155,250	310,500
Port Coquitlam	1.5	1750	9,375	18,750
Port Mann	15	1575	80,625	161,250
Richmond	265	1000	662,500	1,325,000
Semiahmoo Bay	0.2	990	490	980
Sperling Avenue	2	1525	10,250	20,500
Stride Avenue	10	1500	50,000	100,000
Terra Nova	60	1650	345,000	690,000
TOTAL	534		1,854,810	3,709,620

Based on 50% of precipitation over 500 mm as minimum and 100% over 500 mm as maximum leachate generated. Precipitation extrapolated from Wright and Trenholm (1969).

Atwater (1980) evaluated each landfill site in the area for his Fraser River Estuary Study review of landfill impacts. The information and concerns expressed in his report remain valid as leachate outflow has not ceased after closure. Issues arising more recently are the effects of developing the sites. The Leeder, Terra Nova, and Richmond sites are currently being developed with sand preload applied as an initial step. The preload is intended to compress the fill, and forces leachate out. A temporary increase in discharged leachate volume results.

For 1979, Atwater (1980) estimated that the leachates coming from all municipal refuse landfills in the Fraser River estuary area accounted for 2% of the COD, 6% - 7% of the ammonia, 6% of the iron, and about 2% of the zinc entering the lower Fraser each day from all sources. For each tonne of refuse landfilled, an anticipated 5 - 10 kg of solids having a COD of 7.5 - 15 kg will be leached out, along with about 1 kg of ammonia.

Monitoring has been most extensive for leachate collected and discharged to the Annacis STP (table 5). The 5 landfills summarized in table 5 comprise 31% of the maximum estimated discharge from landfills (from table 4). Leachate from the Richmond site (36% of the total) is treated on-site. Remaining landfills presumably account for about 33% of leachate

generated. There is no data to indicate what proportion of leachate at landfills with collection works is captured. Landfill loadings can be crudely estimated by assuming connected-to-sewer, leachate characteristics apply to Richmond and the untreated sites (table 6).

Table 5 LEACHATE LOADINGS FROM SELECTED MUNICIPAL LANDFILLS, 1985

Parameter (kg/day)	Burns Bog	Braid Street	Cottonwood	Kerr Road	Port Mann
Total Solids		1,437		507	1,289
Suspended Solids	131	42			100
Oil and Grease		5			
COD	538	329	58	42	288
BOD5		23	<9		74
TOC			99	17	107
Phenol	<0.7	0.059		0.001	
Chloride		278			180
Fluoride*	<.01	0.1			0.07
Sulphate*	81	18			4.2
Sulfide	<0.1	<0.06			
Total Kjeldahl N		131			93
Ammonia	289	128	13	24	79
Nitrate	5	0.9	0.11	3	
Nitrite	0.1		0.018	0.051	
Phosphate*		0.6			0.14
Aluminum*		<0.3	0.9	0.02	
Arsenic*	<0.1	0.03	<0.2	<0.12	0.002
Barium*			0.1	26	
Boron			0.4	0.95	
Cadmium*	<0.1	<0.004	<0.013	<0.005	0.001
Calcium*	210	108	60	41	171
Chromium*	<0.1	<0.03	<0.02	<0.005	0.003
Cobalt*		<0.03	<0.01	<0.049	
Copper*	<0.1	<0.012	<0.008	<0.005	<0.16
Iron*	17	18	2.3	0.1	37
Lead*	<0.8	<0.045	<0.04	<0.049	0.16
Magnesium*		30	16	19	32
Manganese*	2	1	0.9	0.1	1.1
Mercury	<0.0007	<0.0003	<0.02		
Molybdenum*		<0.06	<0.013	0.01	
Nickel*	<0.1	<0.03	0.3	<0.025	0.01
Phosphorus			10.6		0.6
Silver*		<0.012	<0.02		
Sodium*		154	36		129
Vanadium*			<0.005	<0.005	
Zinc*	0.25	0.062	0.02	0.007	0.26

* May be total or dissolved (Source: GVRD, 1988b)
Blanks indicate no data.
These landfills discharge to GVS&DD sewer and are monitored by the GVRD

Table 6 ESTIMATED MUNICIPAL LANDFILLS LOADINGS, FRASER RIVER ESTUARY AREA

Contaminant (kg/day)	Connected to sewer[1]	Treated on-site[2]	Untreated[3]
COD	1,255	1,457	1,336
Ammonia	533	619	567
Iron	74	86	79
Magnesium	97	113	103
Manganese	5	6	5
Zinc	0.6	0.7	0.6

[1] Includes Braid Street, Burns Bog, Cottonwood, Kerr Road, and Port Mann. These loadings pass through the Annacis STP and are counted as Municipal Effluent loadings
[2] FRHC Richmond Landfill, permit nos. PR 4922, PR6277, PE6276
[3] Includes remaining landfills. Interpolated from tables 4 and 5

The fate of uncollected leachate in the Fraser River estuary area is not well known. Leachate that escapes to the environment may impact either surface waters or groundwater. Leachates that flow a long distance through the ground may be attenuated, but much leachate flows only a short distance before discharging as leachate springs running into ditches or streams. Given the distribution of landfills, their respective sizes, and development trends, the Main Stem may receive the greatest leachate volume, but the greatest impacts may still occur on the small streams.

A MOE monitoring program (Moore, In Prep.) found leachate from the Bear Creek site to be acutely toxic. The leachate discharges into a known salmon spawning area, but the low volume of discharge may reduce potential impacts. Leachate flows from the Kerr Road and Stride Avenue landfills were also found to be acutely toxic, and consist of much more significant flows. Leachate from the Langley City landfill, while not acutely toxic, have resulted in heavy bacterial and fungal growth in Pleasantdale Creek that likely has impacted the fisheries resource. Terra Nova leachate has caused elevated ammonia levels in Como Creek during low flow periods.

Management

All landfills in B.C. require a permit under the Waste Management Act (SBC 1982 Chap. 41), and are required to meet the standards set out in the Pollution Control Objectives for Municipal Type Waste Discharges in British Columbia (MOE, 1975). These criteria were issued after the closure of most small landfills in the Fraser River estuary area, and are now being revised. Objectives for refuse disposal include size, location, monitoring, and control.

Under Section 16 of the Waste Management Act, the GVRD developed a Solid Waste Management Plan which was approved by the provincial government in 1985. The plan was implemented and essentially completed by 1989. The plan has five parts: (1) establishment of the Port Mann landfill as a short term landfill; (2) expansion of the Burns Bog landfill; (3) construction of a Refuse Incinerator Plant in Burnaby; (4) establishment of local transfer stations and resource recovery plants; and (5) promotion of recycling programs under a Recycling Action Plan. Many municipalities have introduced recycling programs ranging from curbside collection, recycling depots, to hazardous waste collection days. These are all intended to reduce the amount of waste discarded in landfills.

The dominant leachate handling method in the area is collection and discharge to the Annacis Island STP. An estimated 3,500 m^3/day is collected from the 5 sewer-connected landfills. Flows may triple or more during sustained rainfall. Leachate from the FRHC Richmond landfill is collected, treated on-site, and discharged to the Main Arm under permit. Collection of the Terra Nova, Leeder Avenue, Langley City, and Stride Avenue leachate would likely capture most of the remaining discharge. However, little work has been done on determining the effectiveness of the collection systems or on the effectiveness of the process provided by the treatment plant. In the case of the Braid Street, Leeder Avenue, and Terra Nova landfills, the GVRD sewer line that would serve the sites is at capacity, and, especially during sustained rainfall, it is possible that not all collected leachate could be delivered to the Annacis STP.

Action Required

Collection and divergence to the Annacis Island Sewage Treatment Plant is the most common leachate management strategy in the estuary. Actions required to manage municipal landfill leachates include:

- Determine captured/not captured leachate ratio. The proportion of generated leachates that are captured and treated for the landfill affected is not well known. While theoretical rules-of-thumb and knowledge of site hydrogeology indicate most leachate is captured, this needs to be confirmed. The proportion of uncaptured leachates that discharge to ground water as opposed to ditches or streams is also not well known.

- Capture all leachates for treatment, using best practical technology and methods. Terra Nova, Leeder Avenue, Langley City, and Stride Avenue landfills are all large

generators of leachate that are not currently hooked-up to the sewer. All leachate may not be captured at sites currently connected to sewer

- Priorize sites based on impacts rather than volume. Some small volume discharges can have major site-specific impacts, and vice versa

- Evaluate effectiveness of primary sewage treatment plant process for treatment of leachates. The Annacis STP provides primary treatment which may not effectively remove many of the landfill leachate constituents. Also, capacity of sewer lines for leachate collection may be exceeded and this needs to be considered

- Estimates of contaminant loadings are poor and should be refined. No accurate idea of landfill leachate loadings to groundwater exists

- Assess impacts at sites for which impacts are currently unknown. Some sites may be "forgotten," these need to be found and evaluated for environmental impact. Consider the relative significance of the sites when setting action priorities

Industrial Refuse Sites

Nature and Magnitude of the Problem

Industrial refuse sites are of two types: ongoing sites for disposal of production debris such as furnace slag and ash associated with a foundry, or cement wastes from a concrete structures firm; and temporary landfill sites accepting inert construction or demolition debris, or other material intended to fill a particular site for development. Wood waste landfills are discussed in the Wood Waste section.

Leachates are generated at many of these sites. The leachate composition is as variable as the material landfilled, some leachate is toxic. There are no estimates of the total amount of leachate generated. Currently, landfill sites are concentrated along River Road in Delta, on the Main Arm.

Management

All refuse sites require a permit under the Waste Management Act (table 7). Some types of landfill activities are exempt from the permitting procedure. These include clean sand used for construction preloading.

Table 7 REFUSE PERMITS ISSUED BY ENVIRONMENTAL PROTECTION, MOE

Permit Number	Name	Refuse Type	Volume (m^3/day)	Comments
Boundary Bay				
PR2550	Reliance Foundry Co Ltd	Foundry waste, sand, gravel	5	Leachate high in metal contamination
PR4441	Cloverdale Demolition	Demolition debris, wood waste	17.6	Dormant from Mar 20, 1980
Main Arm				
PR3867	Con-Force Structures Ltd	Cement wastes, sand, wood	11	
PR4409	Lafarge Canada Ltd	Cement wastes, sand, wood	54	
PR4468	Vito Steel and Barge	Gyproc, wood waste	1,000	Leachate highly toxic
PR4923	David S. Tuba	Concrete waste, clean soil	20,000	No leachate problem
PR4971	Delta Cedar Products	Wood waste	153	
PR5135	C. and I. White	Asphalt waste	7.6	Awaiting final cover
PR5358	G.B. Lawrie	Wood waste	229	
PR7707	Alpha Manufacturing	Demolition and excavation	320	
PR7709	7437 Holdings	Demolition debris	350	
PR7765	Robert Brown	Demolition debris	300	
PR8139	Meadowland Peat Ltd	Demolition debris	240	
PR8169	Robert Brown	Inert industrial	300	Producing leachate
PR8177	ADP Holdings	Inert industrial	50	
Main Stem				
PR1655	Canadian Forest Products	Ash, sand, and gravel	3	High pH, alkalinity
PR1685	United Auto Wrecking	Demolition, metal scraps	760	Leachate generated
PR1910	Parsons Channel Prop.	Sawmill wood wastes	920	
PR2351	Kennametal Inc	Ash, refractory brick	1	Leachate probably toxic
PR2989	BCMOP	Municipal type	3/week	
PR3141	Crane Canada Ltd	Porcelain/clay products	2.3	
PR3417	Domtar	Sawdust, bark, yard refuge	6.5	
PR4428	Baytree Industries	Demolition debris, wood waste	7.6	Fill completed
PR5031	Fletcher Challenge	Municipal type	2.3	
PR6214	Arthur Hayden	Demolition debris	183	
North Arm				
PR1667	MacMillan Bloedel	Ash, sand, slag,charcoal	15.3	Closed May, 1977
PR2086	Western Canada Steel	Ash, cinders, bricks, metal	13.8	Dormant from July, 1988
PR2425	Weldwood of Canada Ltd	Ash, sand, 4% paint and glue	2.3	Leachate probably toxic
PR2510	Bow Valley Res. Services	Ash, sand, gravel, sludge	3	
PR5443	District of Burnaby	Wood waste	260	
PR5936	Paperboard Industries	Paper fiber, sand, wood, metal	5.5 tonnes/d	
PR6574	Meadowland Peat Ltd	Demolition debris, wood waste	400	
PR7276	District of Burnaby	Wood waste, clean fill	max 93,000 m^3	
Miscellaneous				
PR2085	Letson and Burpee Ltd	Foundry waste, sand, grav·i	3	
PR2259	Pacific Disposal Ltd	Demolition mixed inert	38.2	Cancelled July 29, 1986
PR3082	Rober Industries Ltd	Foundry waste, sand, gravel	0.76	Now closed

Note: probable leachate generation to groundwater for all except cement plant wastes and porcelain wastes.
Temporary fill sites now closed are not listed

(Source: Atwater, 1980; WMB files)

Some sites have been contaminated with materials that qualify them as special wastes. Environmental Protection, B.C. Ministry of Environment, is in the process of inventorying these sites and initiating remedial measures under the Special Waste Regulation (B.C. Reg. 63/88) of the Waste Management Act.

Actions Required

Actions required include:

- Monitor and evaluate leachate quantity, quality, and toxicity at industrial refuse sites, including closed or completed fill sites. Estimate leachate generated. Inventory and prioritize sites in terms of impacts
- Develop pollution control objectives for refuse sites
- Develop and evaluate treatment processes
- Encourage Reuse, Reduction, and Recycling initiatives

Industrial Discharges to Ground

Nature and Magnitude of the Problem

Industrial discharges to ground are effluent streams from industrial or commercial facilities that are discharged to land, infiltration pits, ponds, rock pits, wells, or septic fields. They range from relatively innocuous streams such as cooling water dripping from a saw blade in a lumber mill, truck wash waters, and boiler blowdown to potentially more significant sewage or process water discharges.

Discharges to ground require a permit under the Waste Management Act (table 8). Currently, 43 permits for discharges to ground have authorized discharges ranging from 0.5 m^3/day to 2,273 m^3/day, though only 5 discharges are over 123 m^3/day. Nineteen discharges are municipal type discharges of sewage from trailer parks, schools, or animal kennels to septic fields. As long as the septic field has been correctly installed and maintained, no pollution problems should result from these discharges. Similarly, if properly managed, the other discharges should not create pollution problems.

Not all discharges to ground in the Fraser River estuary area are authorized. Operators may not be aware that a permit is required. Of about 20 concrete companies along the river in the estuary for example, only 4 have permits allowing discharges of excess concrete or truck wash water to land or infiltration ponds. Concrete plant discharges are a concern because Fraser River water has poor buffering capacity for alkaline discharges. In cases such as these, the permitting procedure acts as check to ensure that good management practices are followed and environmental impacts are minimized.

Table 8 MOE PERMITS FOR DISCHARGES TO GROUND

Permit	Name	Industry Type	Discharge Type	Volume (m^3/day)	Comments
Boundary Bay					
PE0209	Smith Trailer	Municipal	Sewage	55	Treated effluent to tile field.
PE0218	W. and G. Smith	Municipal	Sewage	29.55	Treated effluent to tile field.
PE0225	M. Gurtitz	Municipal	Sewage	46.4	Treated effluent to tile field, with PE0236.
PE1558	Hazelmere Camp	Municipal	Sewage	22.7	Treated effluent to tile field.
PE3148	School District 35	Municipal	Sewage	54.6	Treated effluent to tile field.
PE4256	Border Sand	Gravel	Process	2,273	Gravel wash water to settling pond
PE4645	Del-Van Constr.	Municipal	Sewage	123	Treated effluent to tile field.
PE4690	Old Yale Invest.	Food	Process	114	Treated effluent to spray irrigation.
PE5478	Sunnyside Villa	Municipal	Sewage	nd	Treated effluent to tile field.
PE6323	School District 35	Municipal	Sewage	24.5	Treated effluent to tile field.
PE7582	J&L Meats	Food	Process	6	Treated effluent to tile field.
Main Arm					
PE0023	Iona Island	STP	Sludge	nd	Sludge waters to sewage lagoons.
PE0161	Titan	Metal	Cooling	55	Clarifer underflow to sediment pond and infiltration lagoon.
PE0387	Annacis Island	STP	Sludge	nd	Sludge waters to sewage lagoons.
PE1928	Imperial Oil	Petroleum	Process	6	Treated stormwater to infiltration bed.
PE2273	Tri Mac	Concrete	Process	46	Truck wash to infiltration pond.
PE5529	B.C. Hydro	Petroleum	Process	2.7	Treated vehicle maintenance shop wash water to rock pit.
PE6943	Spincraft	Metal	Process	5	Treated rinse tank effluent from metal cleanup to infiltration pit.
PE8094	May and Sons	Municipal	Sewage	45.5	Treated effluent to tile field
Main Stem					
PE0183	Alouette Cor. Ctr.	Municipal	Sewage	230	Treated effluent to tile field.
PE2195	Silkwood Ent.	Food	Cooling	3.6	Cooling water to infiltration pit.
PE2350	Kennametal	Chemical	Process	45	Refinery effluent to infiltration pond.
PE2632	Kockums Cancar	Municipal	Sewage	45.4	Treated effluent to tile field.
PE2673	PVC	Municipal	Sewage	91	Treated effluent to tile field.
PE3332*	Lafarge	Concrete	Process	53.2	Truck wash to settling pond
PE3434	Weldwood	Forest	Combined	272	Boiler blowdown to infiltration pit.
PE3874	Bochee Kennels	Municipal	Sewage	3.2	Treated effluent to tile field.
PE5496	Haney Corr. Ctr.	Municipal	Sewage	70	Treated effluent to tile field.
PE5500	Rempel Bros.	Concrete	Process	55	Wash water to infiltration pond
PE7815	Haney Corr. Ctr.	Municipal	Sewage	194	Treated effluent to tile field.
PE7880	A.G. Meynders	Municipal	Sewage	0.54	Treated effluent to tile field.
PE8031	BCMOP	Municipal	Sewage	20.55	Treated effluent to tile field.
PE8106	S. Hardman	Municipal	Sewage	1.4	Treated effluent to tile field.
North Arm					
PE1666	Mac. Bloedel	Forest	Cooling	12	Planer guide cooling water to land.
PE3190*	Tree Island	Metal	Combined	1,350	Treated process and domestic effluent to infiltration pond.
PE3555	Liquid Carbonic	Chemical	Combined	2.3	Occasional miscellaneous discharge.
PE4246	ABC Recycling	Metal	Process	2.27	Treated effluent to infiltration pit.
PE4902	Dayhu Invest.	Municipal	Sewage	22.7	Treated effluent to tile field
PE4962	Hilinex	Forest	Process	0.5	Treated process water to infiltration pit.
PE4963*	Somerville Bel	Forest	Process	15.7	Treated process and wash waters to infiltration ponds.
PE5833	Construction Ag	Concrete	Process	16.2	Truck wash to infiltration pond.
PE6524	Rebar Redi mix	Concrete	Process	5	Truck and aggregate wash water to infiltration pond.
PE6814	Rempel Bros	Concrete	Process	55	Truck wash to infiltration pond.

* Multiple discharges with this permit.
nd no data
(Source: Environmental Protection, MOE, permit files)

Management

Permits for discharges to ground are required under the Waste Management Act. The Waste Management Regulation (B.C. Reg. 432/82) exempts only single or double unit domestic dwellings or discharges of domestic sewage less than 22.7 m^3/day. Specific Pollution Control Objectives for discharges to ground have generally not been developed, but some guidelines may be recommended.

North Fraser Harbour Commission harbor patrols, Fraser River Harbour Commission harbor controls, and Conservation Officer Service surveillance may uncover instances of unauthorized discharges to ground. There is no general strategy to locate unauthorized discharges.

Actions Required

Actions required include:

- Produce inventory of sites with toxic discharges. While some information is available on a site-specific basis, particularly permit data, and some impacts have been identified, particularly for the metal finishing industry, further inventory or overview is required.

- Monitor and evaluate discharge quantity, quality, and toxicity of industrial discharges to ground

- Develop operating guidelines, codes of practice, and awareness initiatives for discharges to ground

- Revise existing pollution control objectives to incorporate objectives for discharges to ground

- Find unauthorized discharges to ground, enact provisions of Waste Management Regulation, as required

Domestic Septic Systems

Nature and Magnitude of the Problem

Properly designed, installed and used, on-site septic tank/tile field systems can remove contaminants and produce better quality effluent than most municipal secondary treatment

plants. However, septic systems can fail. Reasons for failure include installation in areas with a high water table, installation in unsuitable soil, improper construction, installation on an inadequate site, improper design, design performance not achieved, lack of maintenance, and improper use. An estimated 3 - 5% of septic systems in the Puget Sound area have failed (PSWQA, 1986), no similar estimates exist for the Fraser River estuary area. Failing septic systems discharge pathogens, and pose a human health threat.

An estimated 7,000 residences along the Fraser River estuary have septic tanks (GVRD, 1988a). Most of these are in the Serpentine, Nicomekl, and Campbell River watersheds draining into Boundary Bay, and most of the remainder are along the Pitt River. The approximately 135 septic tanks along the North and Main Arms are generally installed below the water table and it is assumed that they do not work effectively because of this.

Contaminants of concern are BOD, suspended solids, ammonia, and pathogens. Estimated BOD and suspended solids loadings are 17,115 kg/year, 1,710 kg/year of ammonia, and a most probable number of 16.3 x 10^{15} fecal coliforms (table 9). While these are all less than 1% of those from the Annacis Sewage Treatment Plant, impacts are on groundwater which may be tapped for drinking water, and on slow moving, low flow tributaries already under stress from other waste sources.

Table 9 ESTIMATED LOADINGS FROM SEPTIC TANKS, FRASER RIVER ESTUARY, 1987

Reach	Residences (estimated)	Loadings (kg/year)			Fecal Coliforms (x 10^{15})
		BOD	Suspended Solids	Ammonia	
FRASER RIVER					
North Arm	15	315	315	30	0.3
Main Arm	120	2,520	2,520	250	2.4
Kanaka Creek	900	1,890	1,890	190	1.8
Pitt River	2,000	4,200	4,200	420	4
Coquitlam River	300	630	630	65	0.6
BOUNDARY BAY					
Serpentine River	1,300	2,730	2,730	275	2.6
Nicomekl River	1,200	2,520	2,520	250	2.4
Campbell River	1,100	2,310	2,310	230	2.2
TOTAL	6,935	17,115	17,115	1,710	16.3

NOTES: it is assumed that only 10% of the actual loadings could enter the waterbody, except for the North and Main Arm where 100% is assumed.
(Source: GVRD, 1988a)

Management

The Health Act (RSBC 1978 Chap. 161) s. 5(mm) allows regulations for the inspection, control, location, design, installation, construction, operation, and maintenance of septic tanks . The regulations are generally administered by municipal health departments or area health units. Few provisions are in place for inspection of septic systems once installed.

The Waste Management Regulation of the Waste Management Act provides a Class A: municipal type exemption for "all discharges emanating from a single or double unit dwelling."

The Canadian Mortgage and Housing Corporation has set septic tank criteria for site appraisal, design, construction, operation, and maintenance (CMHC, 1978).

Action Required

The problem of on-site septic system failures has two parts: maintaining, repairing, and/or replacing older systems; and ensuring that new systems will not fail. Regulated standards can handle the latter. Dealing with older systems is more complex. Alternatives include adopting management and maintenance programs, establishing a regional septic system utility, providing MOH with an enforcement role, requiring permits and associated standards for all systems, increasing resources to deal with inventory and problem correction, requiring realtors to attach property sale information, an annual certificate of inspection and satisfactory operation could be required, education programs, financial assistance for system replacement, requiring low-water use fixtures, establishing a technological assistance office, and providing regional septage disposal sites. Failing septic systems has been recognized as an important component of the Puget Sound area non-point source pollution problem, and these alternatives are being investigated there (PSWQA, 1988).

Actions for the Fraser River estuary area include:

- Explore, develop, and implement initiatives to reduce old and new septic system failures
- Train public health inspectors regarding the signs of failing systems, the criteria for proper design, installation, and use of septic systems, and where to access expertise when needed
- Extend sanitary sewer system to replace septic tanks

Fertilizers and Soil Additives

Nature and Magnitude of the Problem

Fertilizers contain nutrients that are added to soil to increase productivity. The common fertilizer nutrients are nitrogen, phosphorus, and potassium. These are applied in various chemical formulations and in fertilizer type. Nitrogen may be in ammonia or nitrate forms, phosphorus as ortho or P_2O_5, potassium as K_2O. Types of fertilizer are chemical fertilizers, animal manures, compost, and sewage sludges. Land spreading of sewage sludge is discussed in a later section.

Soil additives are inorganic additions other than fertilizers that are intended to improve the chemical, physical, or microbiological properties of soil for crop growth. Included are liming materials such as limestone and hydroxides which are used on acid soils; gypsum, used to increase the rate of entry of surface water into certain soils; and sulfur,and other acidifying agents, used to create a more favorable environment for crops that thrive on acidic soils.

Many of these are also potential groundwater contaminant sources. The important ones in the Fraser River estuary area include manure and compost spreading, discharge of silage and milk parlor effluents, the use of chemical fertilizers, and wood waste use.

Few groundwater studies have been done in the Fraser River estuary area. Manure spreading has been indicted as a cause of nitrate groundwater contamination in the Aldergrove area (Kohut, et al., 1989). Fertilizer nitrogen leaching was monitored for two years at four plots in Delta (Nagpal, 1989). Some studies have been done at Agassiz as well (Kowalenko, 1989).

Management

Optimal fertilizer and soil additive application rates are recommended by the Ministry of Agriculture and Fisheries depending on soil conditions, climate, and other factors. The recommendations are available as guidelines for the various agricultural sectors. Under the Agricultural Waste Control Regulation (In Prep.) to the Waste Management Act and the associated Codes of Agricultural Practice for Waste Management, additions cannot be at a level that results in the seepage, discharge, or escape of contaminants that can cause pollution.

Agriculture Canada, Environment Canada, Fisheries and Oceans Canada, the Ministry of Agriculture and Fisheries, and the Ministry of Environment are working to determine optimal application levels and to determine where problem areas exist.

Action Required

Actions required include:

- Continued initiatives for farm operator awareness of the Code of Agricultural Practices for Waste Management and the associated best management practices

Underground Storage Tank

Nature and Magnitude of the Problem

Underground storage tanks in the Fraser River estuary area are primarily for petroleum products, either gasoline and diesel fuel at commercial fuel outlets or domestic heating oil tanks. There are underground tanks at 545 service stations in the GVRD, and about 75,000 domestic heating oil tanks. As most of the Greater Vancouver area is served by natural gas, most domestic fuel tanks are abandoned, but many still contain some amount of oil. Very few domestic tanks were taken out of service in a systematic way that would have left the tanks environmentally benign.

All tanks are subject to corrosion that may result in groundwater-contaminating leaks. In sewered areas, material from leaking tanks may infiltrate sewer lines and discharged to sewage treatment plants or directly to ditches and streams. In rural areas, leaking tanks could contaminate groundwater supplies.

Management

Underground storage tank systems containing petroleum products are covered in B.C. by an Environmental Code of Practice (CCREM, 1988), which is a set of technical practices designed to protect the environment by preventing product releases from underground tanks and piping. The code covers registration, site assessment, design, installation, upgrading, operation, maintenance, and withdrawal from service of tank systems. The code has been written as a complementary document to the National Fire Code of Canada (NRC, 1985), and is primarily intended to promote environmentally sound management of underground tanks, especially the prevention or early detection of product releases. Domestic heating oil tanks are also covered by CSA Standard B139 - 1976 (first edition: 1957), Installation Code for Oil

Burning Equipment, and CSA Standard B140.0, General Requirements for Oil Burning Equipment. While there are no regulations regarding installation, inspection, and replacement of underground storage tanks, the fire marshall may impose conditions under the Fire Code and thus the code has the force of a regulation.

When leakages occur, the initial response is at the municipal level with the Ministry of Environment getting involved later. Assessment and remediation is supervised by Environmental Safety Officers of the Waste Management Branch under authority of the Waste Management Act. The owner of the leaking tank will normally hire a consultant to determine the extent of the contamination and recommend the best clean-up method.

Petroleum industry initiatives include electrolytic protection, the use of fiberglass lines and tanks, improved inventory and record keeping, emergency response procedures, and de-commissioning site procedures that include tank removal. Programs to replace underground storage tanks that have a high leakage risk have been adopted. Ideally, under the Environmental Code, all tanks older than five years would be checked annually for leakage, and replaced if necessary. There is a backlog of tanks to be inspected and replaced, some operational tanks have been in the ground for over 20 years.

Action Required

Actions required to remedy impacts from leaking underground storage tanks include:

- Inventory abandoned and in-service underground tanks. There are no programs in place to identify and empty abandoned tanks in the FREMP area, though there is such a program for the North and West Vancouver municipalities. In an extensively storm-sewered area where streams and tributaries are culverted, it is extremely difficult to trace groundwater contamination by petroleum products back to the source

- Educate homeowners about the environmental conseqences of leaking residential underground tanks

- Provide incentives for home-owners to empty abandoned tanks. Currently an owner may be required to pay to have his tank emptied and sealed, rather than receiving something for the remaining oil

Wood Waste

Nature and Magnitude of the Problem

Wood waste includes sawdust, hog fuel, chips, bark, butt ends, and debris produced by shake and shingle, lumber, and plywood mills. It is used for plant mulch, soil conditioner, animal bedding, for ground cover and foundation material at equestrian facilities, and as access road and fill material at highway and building construction sites. It is also stored in piles at the mills that produce it. About 1.5×10^6 m^3 of wood waste was produced in 1987 by mills located in the Fraser estuary area (WMB files), and much more was trucked in for disposal from the Mission/Albion area.

In contact with water, wood waste leachates are formed which contain toxic materials such as resin acids, tropolones, terpenes, tannin, lignin, and other extractives. Leachates also contain nutrients that may promote fungal growth and deplete dissolved oxygen levels. Wastes from wood exposed to antisapstain treatments may leach chlorophenols, arsenic, chromium, and copper. The characteristic composition of wood waste leachate varies considerably depending on the species and age of the tree, the part of the tree from which the wood waste originates, the particle size of the wood waste, and the amount of nonwood materials in the wood waste. It is the extractive constituents of wood that gives different species of trees their "personalities" (Slagle, 1976).

As the quantity and quality of wood waste leachate vary, it is difficult to present a typical characterization of leachate, and difficult to predict the environmental impacts of a particular wood waste landfill. Two approaches are to analyze different types of wood waste separately, or determine a "worse case" and analyze it. Western hemlock bark has generally been selected for "worse case" analysis. Though cedar heartwood is considered more toxic, a significant portion of landfilled material is bark, and western hemlock has the most toxic bark in the region (Slagle, 1976). Studies have used hog fuel sized particles to determine the worse possible leachate concentration situation (table 10). The other approach is to sample actual leachate composition and compare to toxic levels (table 11).

It appears that virtually all water bodies in the Fraser River estuary area have been subjected to wood waste leachate impacts. Impact areas are not consistant, but are in different places in different years. Following construction of the Annacis Highway, involving wood waste filling where the highway crossed Burns Bog, wood waste leachate toxicity impacted the viability of the trout habitat in the 112th Street ditch (MOE, 1988). Recent development using large quantities of wood waste as construction fill has lead to concerns in east Richmond (Runyan, 1990). Wood waste leachates from agricultural uses are a concern along the Boundary Bay tributaries.

Table 11
WOOD WASTE LEACHATE COMPOSITION

Parameter	Range (mg/L)	Impact Level (mg/L)
Acidity @ pH 8.3 (as $CaCO_3$)	34 - 1620	11
Tannin and Lignin-like compounds	4.8 - 122 gm 3.5 - 300 range	nd
COD	157 - 715	155
Surfactants	< 0.03 - 0.48	nd

gm geometric mean
nd no data
(Source: Moore, Unpublished data)

Table 10
PRELIMINARY RESULTS FROM A LEACHING STUDY

Parameter	Average Value (mg/L)
BOD	8,000
COD	1,500
Total Carbon	2,500
Organic carbon	2,400
Total Solids	7,300
Volatile Solids	5,400
pH	4.1
Acidity (as $CaCO_3$)	1,000
Tannin and Lignin	1,400
Chloride	1,100
Total Nitrogen	8
Nitrogen (as NH_3)	bdl
Total Phosphorus	5
Sulphate	180
Calcium	150
Potassium	120
Sodium	425
Aluminum	15
Arsenic	0.03
Beryllium	bdl
Cadmium	bdl
Chromium	bdl
Copper	0.007
Iron	12
Lead	bdl
Magnesium	80
Manganese	25
Mercury	bdl
Molybdenum	bdl
Nickel	0.07
Zinc	0.6
Toxicity (96 hr LC_{50}) %	38 - 0.062

bdl below detection limit
Metals are total
Approximate average values after 2.5 months
(Source: Cameron, quoted in Slagle, 1980)

Management

The Waste Management Regulation of the Waste Management Act provides a Class C: industrial type exemption for discharges of wood waste that are applied in a reasonable manner as plant mulch, soil conditioner, animal bedding, and ground cover. Guidelines were issued to Ministry of Environment staff in 1990 (MOE, 1989) to better define what "managed and applied in a reasonable manner" means and to reduce the number of leachate problems.

Management options are a letter of exemption if the discharge is clearly classified under Sec. 11 (1) (c) of the regulation, issue a permit , or give approval.

The Code of Agricultural Practices for Waste Management states that the storage and use of wood waste on farms for acceptable purposes, which does not include landfilling, should be in a manner to prevent the runoff of leachates that cause pollution.

The Municipality of Richmond has issued standards for discharge from wood waste fill/construction sites that are applicable to East Richmond (Runyan, 1990).

Action Required

Actions required include:

- Develop a better idea of contaminant loadings that could be expected from unit amounts of wood waste under varying conditions. This would be useful for predicting impacts and developing guidelines or best management codes for wood waste use
- Develop and adopt standards for discharge from wood waste fill sites
- Reconsider the widespread use of Class C letters of exemption
- Consider the use of municipal bylaws to control wood waste use

Pesticides

Nature and Magnitude of the Problem

Pesticide residues dissolved in soil water may contaminate groundwater. Applications may be from agricultural or domestic sources. Pesticides are also applied to public lands such as parks and transportation or power line right of ways. Little monitoring has been done to determine the extent of groundwater contamination from these sources.

A two year monitoring program of four Delta sites found the presence of atrazine, vernolate, dinoseb, metribuzin, and EPTC in soil. How real the pesticide contamination of groundwater was could not be assessed because of limited data (Nagpal, 1989).

Management

Pesticide application is regulated by the Pesticide Control Act (RSBC 1979, Chap. 322) and the Pesticide Control Regulation (B.C. Reg. 391/81). Pesticide use permits are not required for application to agriculture or private land used for other than forestry, transportation, or public utilities.

Monitoring of wells is undertaken by Agriculture Canada for the Lower Fraser Valley, but this is generally upstream of the estuary area. Monitoring of groundwater is undertaken by the Groundwater Section, Water Management, Ministry of Environment on a special project basis.

Action Required

Action required include:

- Monitoring to determine the extent of groundwater pesticide contamination in the Fraser River estuary area. The current database is weak and needs to be augmented

Salinity

Nature and Magnitude of the Problem

All irrigation water has some dissolved salts which are left behind when water evaporates or is taken up by plants. Salts collect on soil surface unless washed off into groundwater or surface drainage.

Salt water encroachment of water table may occur in areas bordering the sea if freshwater drawn out faster than can be replenished by precipitation. Tidal gates on Serpentine and Nicomekl Rivers are intended to prevent salt water intrusion to these rivers, preserving freshwater for irrigation.

Water withdrawal licenses for irrigation purposes in the Fraser River estuary area total 5.3 million m^3/year (Water Management Branch files), most of this in the Campbell River, Serpentine River, and Nicomekl River systems.

Management

The Water Act (RSBC 1979, Chap. 429) allows for control and licensing of water withdrawal from surface and groundwater. No specific management activities are in place to control soil salinity.

The Minstry of Environment, Water Management Branch, maintains passive tidal gates at the mouths of the Serpentine and Nicomekl Rivers to control saline intrusions into the rivers.

Action Required

Action required includes:

- Occasional monitoring to determine whether groundwater salinity is increasing, or whether salt water intrusion into groundwater is occurring

Spreading of Sludges

Nature and Magnitude of the Problem

The four GVS&DD sewage treatment plants presently produce over 50 tonnes (dry weight) of digested sludge daily. Present sludge handling includes on-site storage at the Annacis and Iona Sewage Treatment Plants, for which space is no longer available, incineration, with air quality concerns at the Lulu Island Sewage Treatment Plant, and ocean disposal at the Lions Gate Sewage Treatment Plant, which is no longer considered appropriate. The GVS&DD has experimented with sludge use as a fertilizer for agricultural use. Another alternative is as a slow-release organic fertilizer on low-productivity forest lands. The GVRD and the UBC Department of Forest Sciences have undertaken a joint research project to study the implications of applying digested municipal sewage sludge to B.C. forest lands. Contaminant concerns rest with the amounts of nutrients, heavy metals, and other pollutants that might reach ground or surface waters. Metro Seattle has developed a full scale sewage sludge disposal program, based on research conducted by the University of Washington Council of Forest Resources, that disposes of approximately 60% of its municipal sewage sludge onto forest lands.

Management

The Ministry of Environment has issued Guidelines for Use Under the Waste Management Act to Control the Discharge of Sludge to the Land. If sludges are contaminated, the Special Waste Regulation applies.

Action Required

Actions required include:

- Continued investigation of the practicality of large scale sludge disposal to land in the FREMP area
- Inventory of candidate sites within the FREMP area, assessment of environmental impacts from sludge spreading at these sites

General Recommendations

Some common themes are evident from discussion of the groundwater contamination sources above. A number of general recommendations can be made:

- **Enhance public awareness regarding groundwater issues**

  Initiatives for public awareness of water contamination in the Fraser River estuary area should include groundwater contaminants, sources, and consequences.

- **Produce inventory of sites with toxic discharges.**

  While some information regarding discharge quantity, quality, and toxicity is available on a site-specific basis, particularly permit data, and some impacts have been identified, further inventory or overview is required.

- **Develop an enforcement and surveillance strategy for the estuary**

  A strategy should include elements regarding unauthorized discharges to ground, failing septic systems, illegal dumping, excessive use of wood waste, and other sources of groundwater contamination.

- **Continue and enhance monitoring efforts.**

  Compared to surface water monitoring, little groundwater monitoring has been done.

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